

Risk Assessment and Control Measures for Chemical Hazards in Stainless Steel Industry- A Review

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ABSTRACT

Chemical hazards are one of the most dangerous hazards occurring in any industries that uses them. Several devastating effects like explosion, environmental pollution, asphyxiation, acid burns, and skin disorders, chronic and acute conditions of several diseases might occur due to the leakage of the poisonous chemicals. This project deals in the control of the chemical hazards in a Stainless Steel Plant using Risk assessment technique (HAZOP) and ensuring proper Engineering Controls as proactive measures later.

Keywords: Chemical hazards, leakage of chemicals, HAZOP, Engineering Controls.

I.INTRODUCTION

A. Chemical Hazard and Need for Risk Analysis

Chemicals can be broken into hazard classes and exhibit both physical and health hazards. It is important to keep in mind, that chemicals can exhibit more than one hazard or combination of several hazards. Several factors can influence how a chemical will behave and the hazards the chemical presents, including the severity of the response

- Concentration of the chemical
- Physical state of the chemical
- Physical processes involved in using the chemical (cutting, grinding, heating)
- Chemical processes involved in using the chemical (purification, distillation)
- Other processes (improper storage, addition of moisture, refrigeration)

Risk assessment and risk analysis of technical systems can be defined as a set of systematic methods to:

- Identify hazards

- Quantify risks
- Determine components, safety measures and/or human interventions important for plant safety

There are several risk assessment systems like HAZOP, JSA, HIRA which are used to identify the chemical hazards and assess the effect of the hazard and probability for the hazard to occur and severity of the hazard.

There are several areas in a Stainless Steel Plant where chemical hazards might occur and are listed below.

B. Areas of Hazards

There are several areas in the steel plant where there is possibility for chemical hazards to take place. The three main units of the steel plant are

- Steel Melting Shop
- Hot Rolling Mill
- Cold Rolling Mill

There are several other auxiliary units that make use of chemicals which is hazardous in nature

- Recirculation Pump House-Indirect Cooling Water System
- Acid Storage And Treatment Plant
- LPG Storage Plant

II.HAZOP STUDY

Jeong et al. (2008) made a qualitative analysis by Hazard and Operability Method (HAZOP) to identify the potential hazards and operability problems

of decommissioning operations and concluded that the decommissioning of a nuclear research reactor must be accomplished according to its structural conditions and radiological characteristics and radiation exposure must be controlled to within the limitation of the regulation to perform the dismantling work under the ALARA principle safely.

Khan and Abbasi (2001) proposed optimal risk analysis (ORA) which involved the following: hazard identification and screening, hazard analysis using qualitative hazard assessment by optimal hazard and operability study (OPT HAZOP) and probabilistic hazard assessment by modified fault tree analysis (MFTA). Consequence analysis which include development of accident scenarios and damage potential estimates and Risk estimates.

Qureshi (1988) had done a Hazard and Operability Study (HAZOP) in which potential hazards and identified by looking at the design in a dynamic manner. 1) To identify the nature and scale of the dangerous substances; 2) To give an account of the arrangements for safe operation of the installation, for control of serious deviations that could lead to a major accident and for emergency procedures at the site; 3) To identify the type, relative likelihood and consequences of major accidents that might occur; and 4) To demonstrate that the manufacturer (operator) has identified the major hazard potential of his activities and has provided appropriate controls.

L. Kotek et.al, have prepared a qualitative HAZOP analysis technique that uses a systematic approach to identify possible deviations from normal operations and ensure that appropriate safeguards are in place to help prevent accidents with keywords for generating deviations from safe condition. It is based on developing scenarios and finding the causes deviations, to identify safety functions and estimate the final effects, but it more complements the assessment of severity and probability of each scenario - it allows selecting the most important preventive recommendations for implementation.

Feng Wang et.al, designed an intrinsic safety for petrochemical plant. As we know that there is potential for fire, explosion and toxic gas release. He has taken a Hydrogenation plant for which HAZOP analysis was carried out. Application of the method is not only easy to identify problems in design to avoid omissions and errors, but also make up for the lack of analysis and design experience to improve the design efficiency. It provides a guiding idea and practical method for the intrinsic safety design of the petrochemical plant.

III.SENSOR AND ACTUATOR FOR CHLORINE GAS LEAKAGE

Gengzhi Sun et.al has reported for the first time that an electrochemical gas sensor modified with multi-walled carbon nanotubes (MWNTs) film as electrocatalyst was fabricated for the determination of chlorine (Cl_2). They compared MWNTs and graphite in terms of their electrochemical properties using cyclic voltammetry. Cl_2 gas was allowed through the cathode surface of the sensor and the resulting galvanic effects were monitored. Results indicated that both of the MWNTs and graphite have the electrocatalytic activity for the reduction of Cl_2 while the MWNTs-modified electrode exhibited a higher accessible surface area in electrochemical reactions, excellent sensitivity, stable response, reproducibility and recovery for the determination of Cl_2 .

Nobuhito Imanaka et.al, fabricated a chlorine gas sensor from monovalent Cl^- anion- and trivalent Sc^{3+} cation-conducting solid electrolytes. The sensor exhibited reproducible response, and time to reach 90% response was less than 3 min. Good linearity was observed between the sensor EMF output and the logarithm of the chlorine gas concentration, and the results obey ideal Nernst equation.

Toshihiro Miyata, et.al, has developed a gas sensor using Cu-phthalocyanine (CuPc) thin films for high sensitivity chlorine (Cl) gas detection. The CuPc thin film gas sensors exhibited an increase of conductivity with exposure to Cl gas. The sensing properties of the CuPc thin film gas sensors were strongly dependent on the preparation conditions of CuPc thin films. The highest sensitivity for Cl gas was obtained in the gas sensor using CuPc thin film prepared under the optimized preparation conditions: substrate temperature of 170°C , evaporation temperature of 475°C and film thickness of 50 nm. It was found that Cl gas detection was realized at a minimum concentration of 0.18 ppm.

Godfrey C. Onwubolu focused on the mechanical actuator systems that consist of hydraulic and pneumatic systems. He has found that hydraulic and pneumatic systems are similar except that while a hydraulic system uses an incompressible fluid as the working medium, a pneumatic system uses air, which is basically compressible. The advantages of using air as the working medium are that it is readily available and no recycling is necessary. The leakage of air does not create a threat to safety as it is non-flammable. It has negligible change in viscosity, which controls the system's performance. The major components of hydraulic and pneumatic systems are pumps

(compressors for pneumatic systems), valves, and receiving units such as motors. Pumps are used to supply the high pressure that the mechatronic system requires. The three types of pumps that are most commonly used are the gear pump; the vane pump; and the piston pump. For a clockwise rotation of the gear in gear pumps, fluid is carried between the gear teeth in the same direction from the inlet to the high-pressure discharge side of the pump. The meshing teeth seal the fluid and prevent it from returning to the low-pressure side. In vane pumps, the rotor rotates in a counterclockwise direction, and a large amount of fluid is carried from the inlet to the outlet. This results from the eccentricity of the center of the rotor with respect to that of the housing. The net flow of fluid is a function of the eccentricity, and when it is varied, the vane pump can then be used as a variable-delivery pump. In axial piston pump, the pistons are parallel to and located in the rotor, which is axially driven by the shaft.

B.Gorissen et.al. has presented a theoretical and experimental analysis of a balloon-type compliant micro-actuator. Finite element modeling is used to describe the complex behaviour of these actuators, which is validated through prototype experiments. Prototypes with dimensions ranging from 11mm x 2mm x 0.24mm to 4mm x 1mm x 0.12mm are fabricated by a newly developed production process based on micro milling and micro moulding. The larger actuators are capable of delivering out-of-plane strokes of up to 7mm. Further, they have been integrated in a platform with two rotational and one translational degree of freedom. Compliant pneumatic micro-actuators are interesting for applications requiring large strokes and forces in delicate environments. These include for instance minimally invasive surgery and assembly of micro components.

Ahmad Athif Mohd Faudzia et.al, a controller design for simulation control of an IPA system using Proportional-Integrative (PI) controller and pole-placement feedback controller. Before the controller is designed, model identification is used to obtain the plant using transfer function. The flow for the controller design starts with the theory, mathematical calculation, procedures and the implementation of the simulation control by using MATLAB software. Furthermore, simulation results are compared and analyzed to illustrate the performance of the proposed controllers. Intelligent Pneumatic Actuators (IPA) is used for application that requires better control and accuracy.

Andrey Somov,et.al, have proposed a wireless sensor-actuator system which aims at quick gas detection and immediate isolation of gas leak source. This low power wireless sensor node includes catalytic

gas sensors, micro processing unit and wireless transceiver which communicates with wireless actuator using ZigBee / IEEE802.15.4 standard and BACnet protocol. Wireless actuator consists of power management circuit, micro processing unit and gas valve. The experimental results demonstrate the sensor node long lifetime while fulfilling performance requirements, quick detection of a hazardous gas and fast actuation time. Wireless Sensors Networks (WSN) has recently been applied in a number of hazardous gas detection applications.

R.K. Gangopadhyay et.al, have presented a case study on an accident where there was accidental release of Chlorine gas from a Chlor-Alkali industry. They have studied all the probable causes for the accident which was poor maintenance of valves and improper training. Furthermore they have discovered that the industry didn't have an onsite and offsite emergency plan. They have provided various recommendations.

T.S Fountain et.al, have developed an automation of Ultra High Vacuum metal actuators using load amplifiers. Generally the UHV metal actuators are manually operated. The forces required to operate the UHV valves are enormous and high pressure is applied by humans which may cause injuries. Hence this paper a load intensifier is used multiplies the applied force many times at the point of closure and transfers the load to the sealing edge. The device has been used successfully on valves with tube sizes up to 64 mm o.d. Testing has included high temperature bakeout and life testing, which indicates that the highly repeatable action prolongs the life of the sealing pad and provides a very reliable uhv seal.

IV.TREATMENT OF SPENT ACID IN STAIN STEEL PICKLING

Burkhard Schmidt et.al, have developed a filtering system based on reverse osmosis to separate the acids and metals from the rinsing water. A pre-filtering method necessary for reverse osmosis was tested. Since the composition of permeate is not applicable for direct reuse in the rinsing zone, post-treatment methods were examined. Amberlite IRA67 ion exchange resin was tested for treatment of reverse osmosis filtrate (pH adjustment). For the recovery of the mixed acids, the concentrate of reverse osmosis was further treated with electrodialysis. On the basis of these results, a regeneration concept was developed, in order to close the rinse water loop. The proposed rinse water recycling concept reduces the overall usage of water. The concentrated part of used rinse water will be fed to pickling acid regeneration plant, where nitric and

hydrofluoric acids can be separated and recycled back to the pickling use. The tests were carried out mainly in one of Outokumpu's production plants in Sweden. Membrane technique was used for rinse water treatment.

Magdalena Regel-Rosocka has reviewed all the available techniques available for the regeneration of the spent pickling solution from steel processing industries. This review presents various techniques of regeneration of spent pickling solutions, including the methods with acid recovery, such as diffusion dialysis, electro dialysis, membrane electrolysis and membrane distillation, evaporation, precipitation and spray roasting as well as those with acid and metal recovery: ion exchange, retardation, crystallization solvent and membrane extraction. Advantages and disadvantages of the techniques are presented, discussed and confronted with the best available techniques requirements. She has said that the best available techniques for regeneration are electro dialysis, diffusion dialysis and crystallization. However, in practice spray roasting and retardation/ion-exchange are applied most frequently for spent pickling solution regeneration. She has suggested that "waiting for their chance" solvent extraction, non-dispersive solvent extraction and membrane distillation should be followed because they are well investigated and developed. Environmental and economic benefits of the methods presented in the review depend on the cost of chemicals and wastewater treatment, legislative regulations and cost of modernization of existing technologies or implementation of new ones.

Frank Rögener et.al, studied about the composition of the metals in the spent pickling acid from stainless steel production. They have summarized that in stainless steel production a defined surface finish of the products is gained by pickling with aggressive acids. However, pickling lines generate significant amounts of waste products, such as metal oxide particles, metal enriched acid solutions and metal containing neutralization sludge from waste water treatment. Thus, valuable metals, such as chromium and nickel, are irrecoverably lost. Additional treatment steps for metal recovery can contribute to a sustainable production. Thus, in the current study the application of membrane electrolysis for nickel recovery from spent pickling solutions was investigated. To proof the industrial application, the investigations were carried out with both, synthetic and industrial solutions. Parameter adjustment included the variation of feed metal concentration, current density, and concentrate conductivity. It could be shown that elemental nickel can be recovered, when iron is removed from the solution. Otherwise, the deposited product consists of

metal oxides and hydroxides. Both, current efficiency and specific product deposition rate increased with increasing current density. Deposition rate was not influenced by the concentrate conductivity. The valuable metals recovered by membrane electrolysis can be fed back to internal or external recycling. Thus, the formation of highly hazardous waste is avoided and natural resources can be preserved.

Anupam Singhal et.al, have developed a new method for the disposal of stainless steel pickling sludge. They have used X-ray diffractometer analysis of stainless steel sulfuric acid pickling bath sludge and found that it contains FeCr_2O_4 , NiCr_2O_4 , NiCrO_4 , and Cr_2O_3 , which do not dissolve in the acids. X-ray fluorescent spectroscopy (XRF) study reveals that chromium concentration in the sludge is as high as in stainless steel, whereas nickel concentration is on lower side and iron is the major constituent of the sludge. Cement-sludge sand mortar cubes have been prepared in the laboratory. Compressive strength of these cubes decreases linearly with increase in sludge content. As per US EPA TCLP test, heavy metal (Cr and Ni) concentrations are negligible in leachate of cement-sludge sand mortar cubes at 28 days of curing. Hence, they found that cement-sludge sand mortar cubes can be made for safe disposal of sludge.

V.DESIGN OF JIB CRANE FOR HF HANDLING

Sandip D. Shinde has created a module that standardizes the jib crane design by "F.E.M rules" and parametric modelling. Standardization of jib crane design procedures enables designers to develop their own jib crane automation modules for entire jib crane design applications. Since main effort and time for implementation of the jib crane design procedures are generally spent for interpretation and explanation of the available jib crane design standards, a computer-automated access by using parametric modeling to the available standards may improve speed, reliability and quality of the design procedures. Starting from the fact that components of jib cranes are generally composed of similar mechanical and electrical sub-components independent of the crane type, a general component tree of jib cranes is developed for automation purpose. Design Modules of cranes are defined from the developed component tree of the cranes based on the available design procedures. Independent Design Procedures are defined as atomic design modules of the jib crane design procedures by considering computational approaches and rules in the "F. E. M. Rules" for each jib crane component. The "F. E. M. rules" is selected for this purpose because of its widespread use and established popularity among the jib crane manufacturers. Access to the "F. E. M. Rules"

from any design procedure is fully automated by using a systematic approach of parametric modeling. The parametric model can be used for various jib crane design cases as well as further for optimization.

Hanjun Pu, et.al have developed a dynamic model for load-lifting system of the crane with which a high precision direct precise integration method was proposed for calculating the dynamic loads of the system. The dynamic characteristics of the general crane which used the traditional step speed regulation and advanced crane which used the variable frequency speed control technique were discussed. Calculating results show that the advanced have much smaller dynamic loads than the general in the same case. This method, with the advantages of high accuracy and taking less computing time, is simple and effective to analyze the dynamic characteristics of the crane system.

VI.DISCUSSION AND CONCLUSION

- Identification of Chemical Hazards in a Steel Industry plays a vital role in preventing Explosions, Fire and Toxic Gas release. HAZOP helps in indentifying all the possible hazards and their effects, and source of hazard thereby preventing it.
- Also several papers have studied about control system for chlorine leakage and Sensor and Actuator system is studied.
- Several methods for Jib Crane design for handling HF acid have been studied.
- Several methods for the treatment of Spent Pickling Acid id reviewed.

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